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Distress and Worry as Mediators in the Relationship between Psychosocial Risks and Upper Body Musculoskeletal Complaints in Highly Automated Manufacturing

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Abstract. As a result of an upward trend in automation, the requirement for supervisory monitoring and consequently, cognitive demand has increased in automated manufacturing. The incidence of musculoskeletal disorders has also increased in the manufacturing sector. A model was developed based on survey data to test if distress and worry mediate the relationship between psychosocial factors (job control, cognitive demand, social isolation and skill discretion), stress states and upper body musculoskeletal complaints in highly automated manufacturing companies (n=235). Cognitive demand was shown to be related to higher distress in employees. The data raise the question about the link between job control and stress and MSD complaints in highly automated work settings.

Keywords: Psychosocial risks, musculoskeletal disorders, automation

1 Introduction

The globalisation of financial and product markets are increasing international competition, resulting in rapid technological change and expectations for higher performance at both the corporate and individual levels [35]. This has led to an emerging trend of work intensification or an increase in workload and work pressure [6]. The sixth European Working Conditions Survey (EWCS) confirms that the concept of 'intensive work' is persistent across Europe [10]. Another European survey found the most frequently reported change in companies is the use of new technologies [9]. In line with these changes, there is an upward trend in automation and human-robot collaboration within manufacturing sectors [21]. While automation has brought improvements in reducing employee exposure to hazardous and physical work, the shift towards predominantly automated processes will inevitably impact employee health in other ways.

Advancements in industrial automation technology have led to increases in mental workload for operators [17]. Increased cognitive demand for operators acting as system supervisors is likely to arise from the requirement for additional monitoring of automation [42], [22]. Sustained attention has therefore become a dominant component of job content in modern manufacturing. [36] has shown that increasing automation actually increases mental workload rather than reducing it, as might be expected. With the continued introduction of automation, it would be expected that the incidence of WRMSDs would also decline, but this does not appear to be happening. A recent HSE UK report on the incidence of work related musculoskeletal disorders has shown that manufacturing industries still have one of the highest incidences of WRMSDs with 'process and machine operatives' having the highest rates [20].

WRMSDs refer to a broad range of inflammatory and degenerative conditions that affect the body's muscles, tendons, ligaments, joints and blood vessels [37]. Across the 27 EU Member States, WRMSDs represent the most common work related health disorders [7]. Traditionally, musculoskeletal disorders are associated with physical and repetitive jobs; but in recent years, psychological stress has also been shown to play a significant role in the aetiology of these disorders [18], [27], [14]. This broadens the focus on WRMSDs to work environments with challenging psychosocial conditions. The fifth European Working Conditions Survey (EWCS) found that musculoskeletal disorders directly related to physical working conditions are in decline while WRMSDs related to work overload and stressful working environments are on the increase [8]. Similarly, the sixth EWCS reported that exposure to posture related risks has declined while many blue collar workers still remain exposed to psychosocial stressors such as high levels of work intensity and low levels of autonomy [10].

Psychosocial stressors can contribute to the aetiology of WRMSDs, but can also solely trigger their development through psychogenic pathways by increasing muscular tension or changing motor control of the muscles [32], [30]. Stress-induced muscular activation can lead to muscular tension and discomfort, which has been considered an early sign of the development of musculoskeletal disorders [40], [16]. Psychosocial risks can lead to work-related stress. Work-related stress is the response people may have when presented with work demands and pressures that are not matched to their knowledge and abilities and which challenge their ability to cope [43]. Work-related stress was found to be the second most common work-related health problem across the EU15 [11].

In highly automated manufacturing environments, where human operators carry out limited physical work but act as the supervisory controller for the process, psychosocial factors are likely to contribute to the development of musculoskeletal disorders. Automation can result in increased workload demands, lower job control, reduced skills [1], increased work pace, reduced social interaction [2], higher cognitive demands [33], and increased job insecurity [4], [3]. There is evidence that automating tasks can add to the existing psychological demands and stressors within a manufacturing environment [41], [29], [34]. The mechanisms linking psychosocial factors to WRMSDs are not clearly understood. Several theoretical models with contradictory reviews [39], [32], [12] have been proposed to interpret these mechanisms but none fully explain the relationship. One possible shortcoming with

current models is that they are based on interactional stress theories such as the demand control model [23]. While these models have been useful in illustrating the role of some psychosocial factors in the workplace, the approach that a stressor causes a strain without always considering further complexities like individual differences, coping and appraisal processes could be viewed as narrow in focus [31]. Psychosocial stressors that are applicable in automated manufacturing include job control, social isolation, cognitive demand and skill discretion.

2 Method

The survey was developed to study patterns of psychosocial stressors (cognitive demand, job control, social isolation, skill discretion) or stress states and their relative patterns with incidence of upper limb musculoskeletal complaints.

A questionnaire survey was compiled which encompassed previously validated questionnaires to measure variables of interest as described below. These included sections of the Copenhagen I & II Psychosocial Questionnaire, an amended version of Standardised Nordic musculoskeletal questionnaire [26] and the Short State Stress Questionnaire [19].

This was a cross-sectional survey distributed across five companies (one medical devices, one semi-conductor, one electronics, two pharmaceutical) in four sectors. Companies were selected on the basis that they had very high levels of automation. While the production layout and tasks were different in each company, each survey employee worked 12–hour shifts with monitoring activities accounting for the dominant proportion of their job content. A total of 235 individuals (188 male, 47 female) completed the hard-copy survey questionnaire. Convenience sampling [13] was undertaken due to restricted access to employee information within participating companies. The companies gave access to the researchers to distribute the questionnaires while employees were on day shift. Questionnaires were distributed directly by the researcher (F.W.). The study was approved by the Ethics Committee, University of Limerick, Ireland.

The questionnaire was distributed to personnel who met the following inclusion criteria: they were between 18 and 65 years of age and they spent at least 70% of their working shift monitoring an automated manufacturing process using a computer interface.

3 Results

There were 235 respondents in total. The characteristics of the observed variables are shown in Table 1. Eighty percent of participants (188) were male and 20% female (47), 20% (47) were in the 21-30 age group, 41.3% (97) were in the 31-40 age group, 27.7 % (65) in the 41-50 age group and 11.1 % (26) were in the 51-60 age group.

The 105 respondents from the semi-conductor company were based in a control room completely removed from the automated process. The seated work stations each had 4-5 computer screens from which they monitored the manufacturing process for 100% of the working shift. The electronics company employees (34 responses) had sit/stand work stations located along the process assembly line. Each workstation had 1-2 computer screens through which the operator monitored that section of the process. Monitoring took place for approximately 70% of the working shift. The medical devices company (49 responses) had seated work stations with 2-4 computer screen located in front of the main production line. The operators spent approximately 70% of the time monitoring the process. Both pharmaceutical companies (39+7) had control rooms located within the area of the process being monitored. Each control operator was seated and attended to between 2 and 4 computer screens, for approximately 75% of the work shift.

Table 1 presents one-way analysis of variance results between the key study variables. Kruskall Wallis was reported for upper back and cognitive demand as these variables were not normally distributed. Levenes test of homogeneity of variance was violated for neck (Sig 0.05), upper back (Sig 0.01), lower back (Sig 0.01) and cognitive demand (Sig. 0.02) so the Welch test was reported for these variables. The results show that there is no significant difference between companies in relation to the musculoskeletal complaints and job control at the 5% significance level. However, there is a significant difference between companies in relation to cognitive demand, social isolation and skill discretion.

Figure 1 gives an overview of the differences in the rates of reporting for four musculoskeletal complaints (neck, shoulders, upper back and lower back). In terms of prevalence of the WRMSDs, the electronics sector employees reported the highest level of shoulder, upper back and lower back complaints. Respondents in the pharmaceutical sector reported the highest level of neck complaints.

Figure 2 gives an overview of the COPSOQ scores across the sectors. Overall, cognitive demand (mean=67.2) scores were highest, followed by social isolation (mean =60.46), skill discretion (mean =53.63) and job control (mean = 43.83).

Table 2 presents the pearson correlation coefficients for the independent variables and the mediating variables. Correlations between the psychosocial factors were moderate (0.24-0.60) which is consistent with existing literature. While distress and task engagement were correlated ($p < 0.01$), low correlation was found between distress and worry which confirms that these factors measure contrasting aspects of stress.

Table 1. Descriptive statistics and ANOVA results on comparison of study variables by industrial sector.

Variable	Mean (SD)	One-way ANOVA	P-value
Cognitive Demand	68.39 (21.28)	$\chi 2(3)$ n=235=25.56	P<0.01
Job Control	44.28 (16.17)	F(3,234)=2.23	P=0.09
Social Isolation	62.52 (15.14)	F(3,234)=9.006	P<0.01
Skill Discretion	55.52 (22.08)	F(3,234)=5.243	P<0.01
Neck	0.41 (0.49)	Welch (3,96.16)=0.815	P=0.48
Shoulder	0.46 (0.49)	F(3,234)=0.334	P=0.80
Upper back	0.28 (0.45)	$\chi 2(3)$ n=235,=5.120	P=0.16
Lower back	0.57 (0.50)	Welch (3,98.53)=1.7	P=0.16

Table 2. Pearson correlation coefficient matrix of the measured variables

	Cognitive Demand	Job Control	Social Isolation	Skill Discretion	Distress	Task Engagement	Worry
Cognitive Demand							
Job Control	0.49**						
Social Isolation	0.24**	0.25**					
Skill Discretion	0.34**	0.37**	0.60**				
Distress	0.12	-0.13	-0.20*	-0.17**			
Task Engagement	0.24**	0.27**	0.25**	0.27**	0.01**		
Worry	-0.01	0.18**	-0.01	0.02	-0.01	-0.03	

**Correlation is significant at the 0.01 level

*Correlation is significant at the 0.05 level

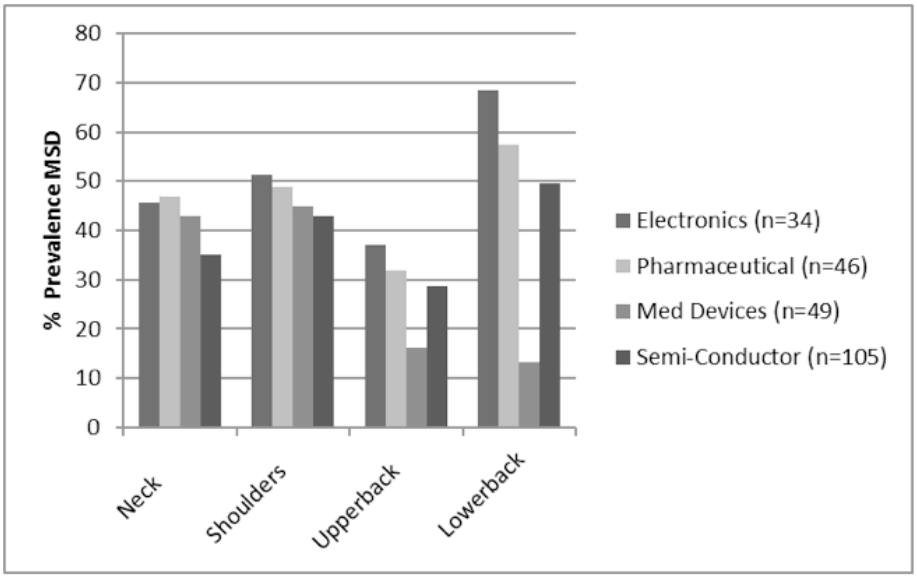

Fig. 1. Prevalence of self reported MSD complaints by sector in previous 12 months

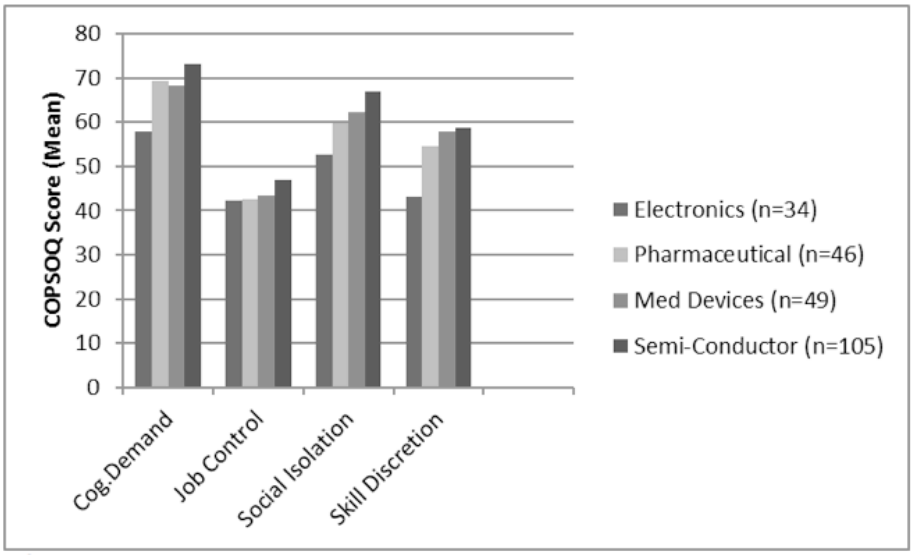

Fig. 2. Mean psychosocial scores by sector

4 Discussion

To date, few studies [5], [15] have incorporated the transactional stress framework [28] in models to link psychosocial stressors to WRMSDs. Stress has not usually been divided into specific components within psychosocial model frameworks in the literature to date. It is widely accepted that stress has both positive and negative effects on humans, but existing models have not considered both effects in their design. In addition to this, there are few examples of formal statistical models testing for significant mediation between psychosocial risks and musculoskeletal disorders in the literature [24]. The next phase of the current study is to tests if a statistical model can be applied to these data to assess if it is in fitting with the transactional stress framework. Such model would attempt to measure stress in the form of three stress state variables which account for individual differences relating to mood, confidence and motivation. That model would formally test if these stress states mediate the link between specified psychosocial stressors and WRMSDs in modern highly automated manufacturing companies. We propose assessing this using Structural Equation Modelling approaches.

5 Conclusions

High incidences of self-reported musculoskeletal complaints were reported from a cross-sectional multi-sector group working in highly automated environments that carry out low levels of physical work. It is evident from the study outcomes that psychosocial factors are likely to play a role in the development of musculoskeletal disorders in these work environments.

Since the high levels of vigilance required in highly automated environments are the main source of cognitive demands, it is proposed that the cognitive demands of prolonged monitoring lead to higher levels of distress in employees. As a result of this higher levels of shoulder and lower back pain are likely. A link between high levels of sustained attention or vigilance and upper body musculoskeletal complaints should be considered by industrial practitioners.

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